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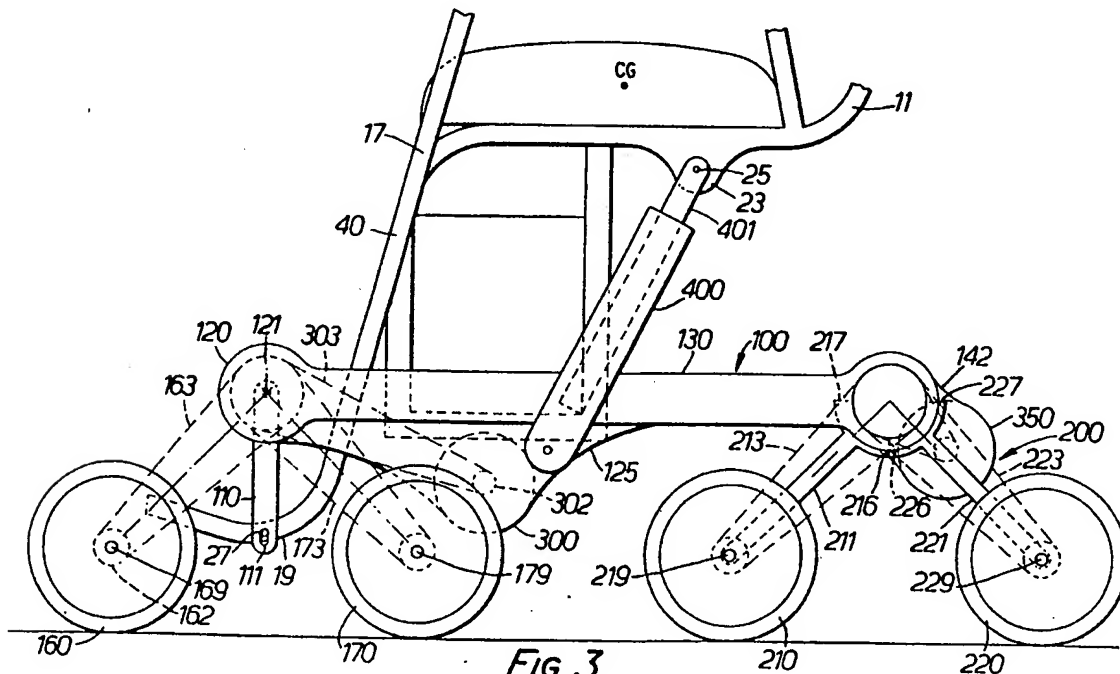
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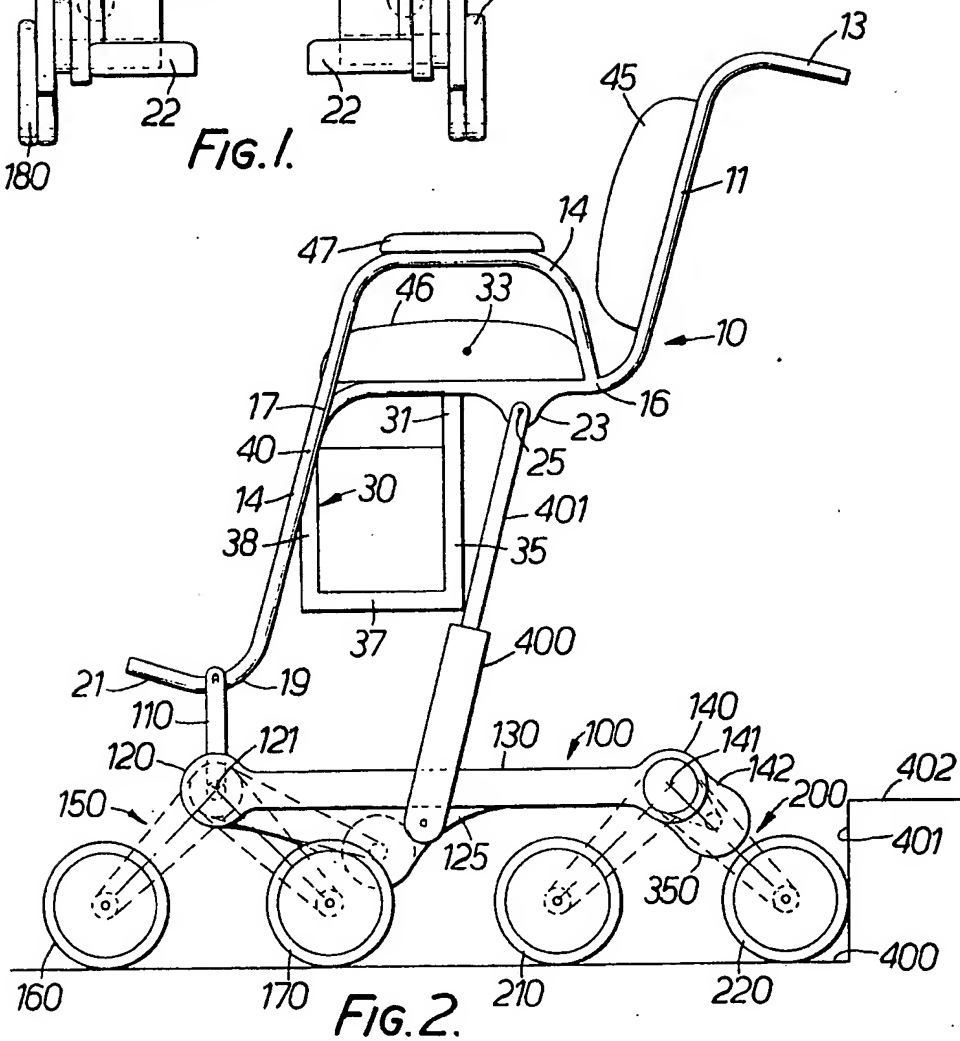
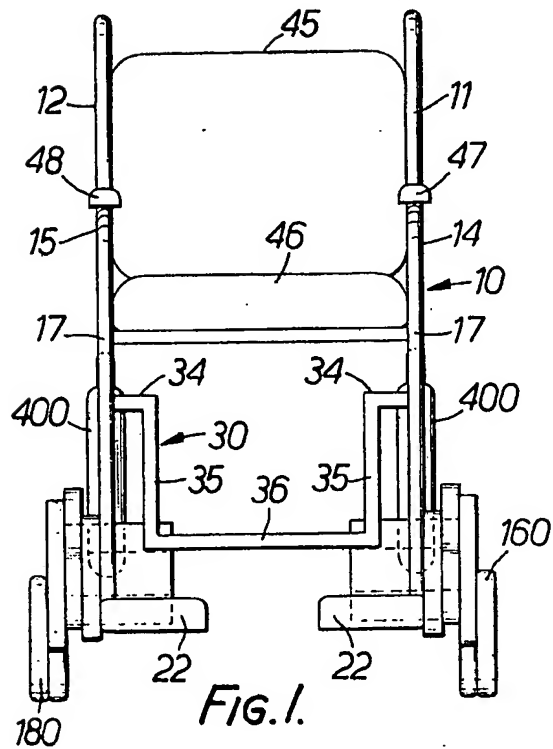
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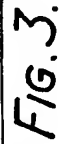
(54) Stair climbing devices

(57) A stair climbing wheelchair comprises a chair (11-17) mounted on a chassis (100) having at each corner a wheel assembly consisting of a pair of wheels (eg 210,220) mounted on arms (eg. 211,211), the wheels being drivable about their own axes and the arms being drivable about the common axis (eg 121) by which they are connected to the chassis. The chair is connected to the chassis via pivoted links (110) at the front and by extensible cylinders 400 at the rear so that the chair can be kept horizontal whilst the chassis is inclined as the wheelchair goes up and down stairs and so that the chair can be raised and lowered relative to the chassis while the chassis remains horizontal. To ascend and descend stairs the wheels and arms are appropriately driven by drive mechanism in response to signals from sensors which sense wheel contact with risers and/or treads.



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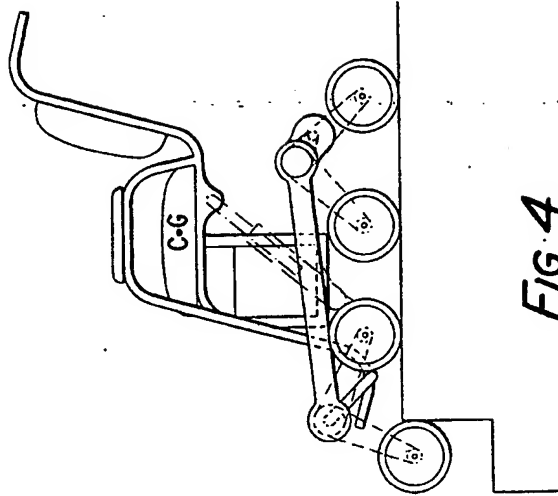


FIG. 4.

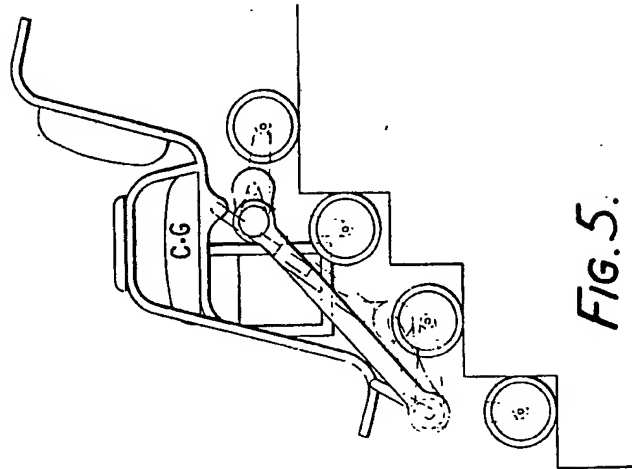


FIG. 5.

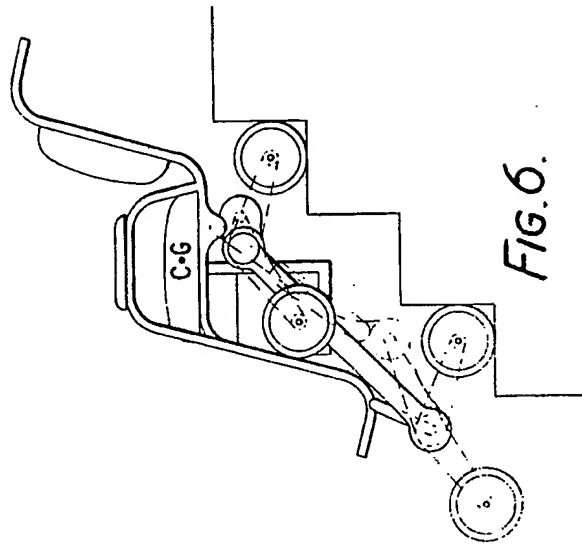
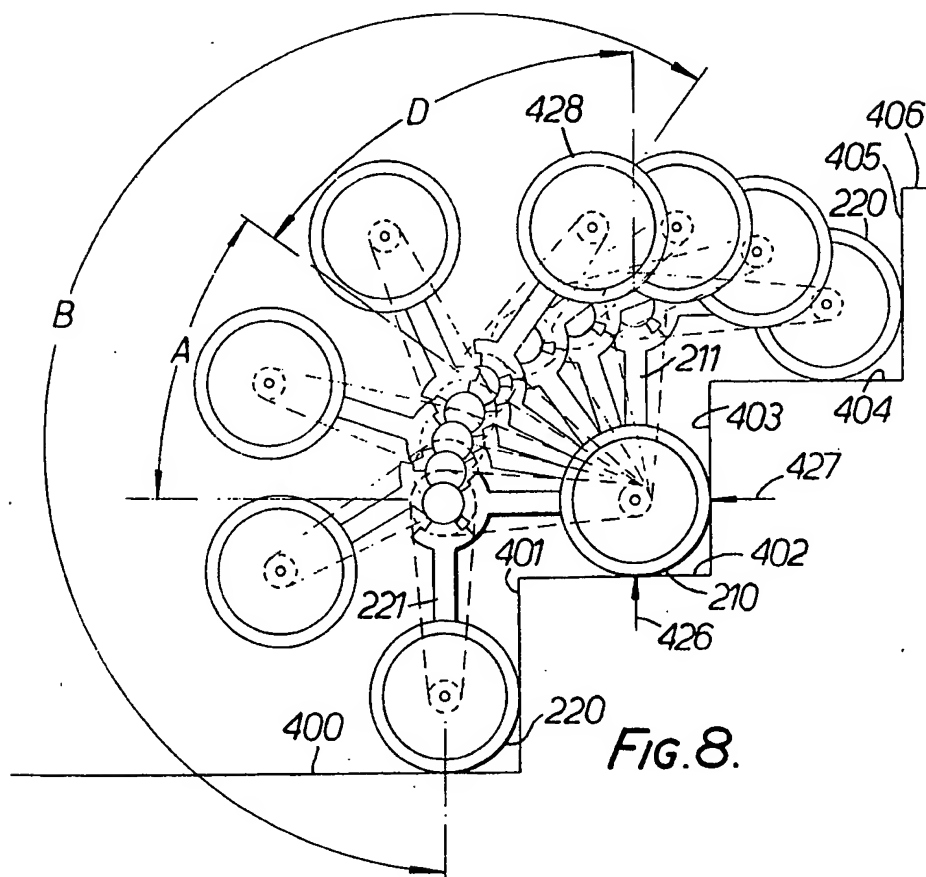
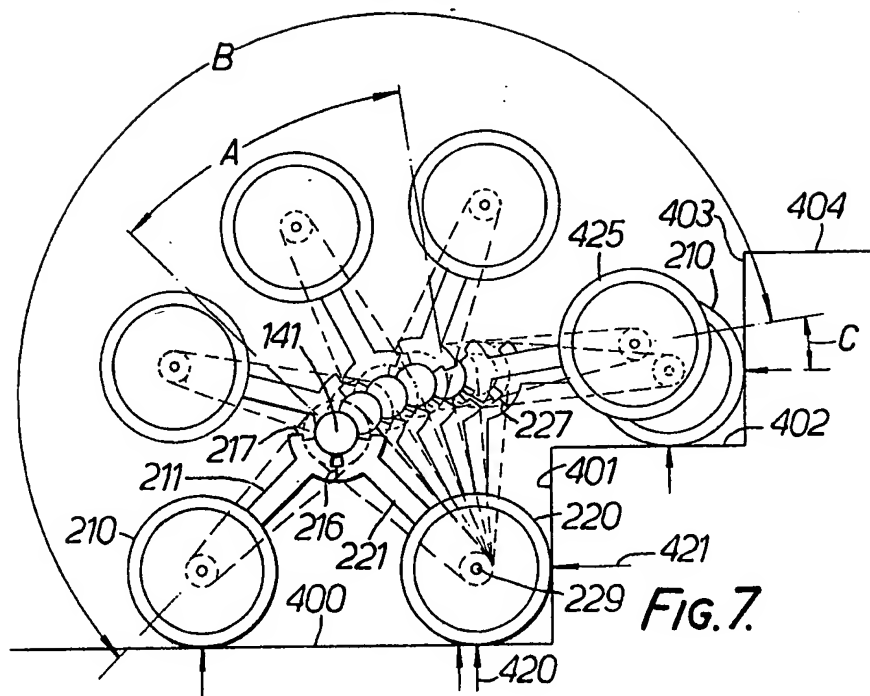
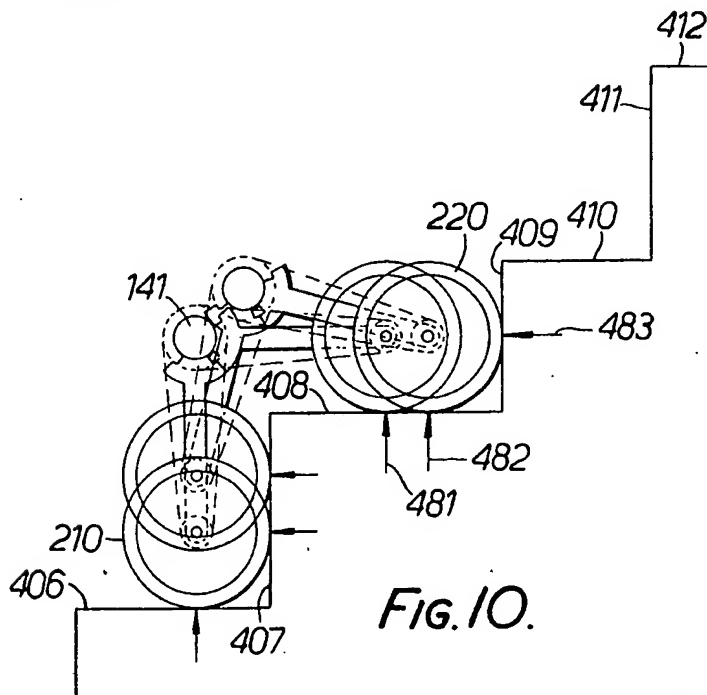
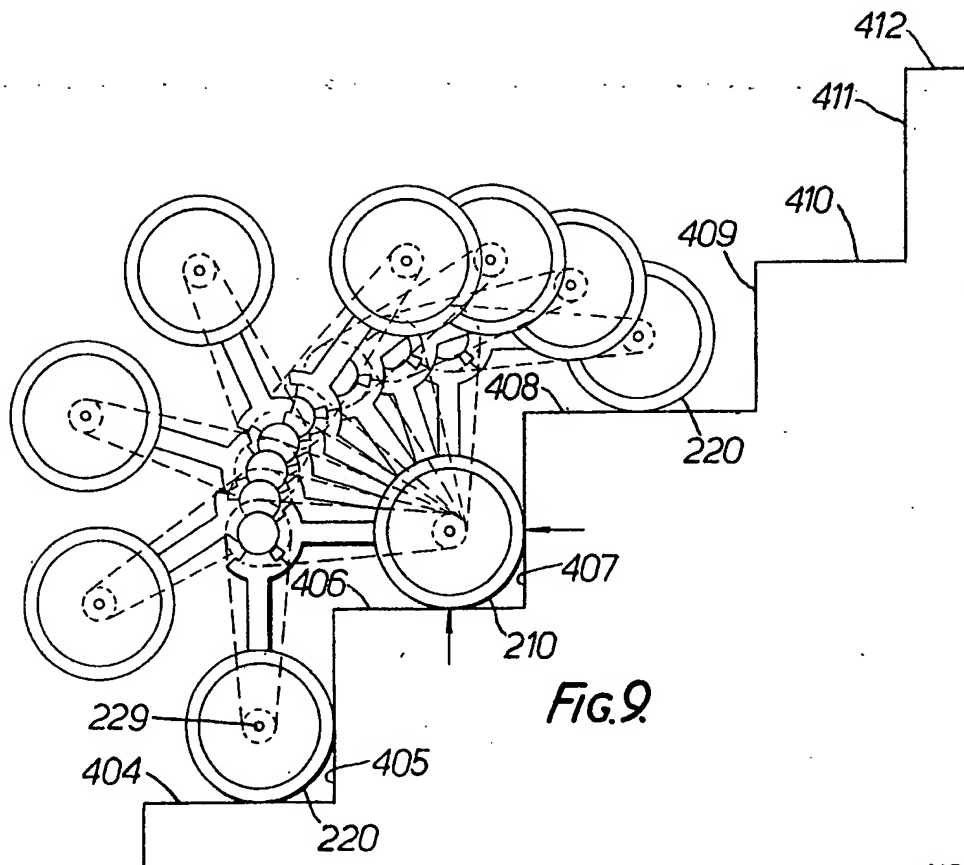


FIG. 6.

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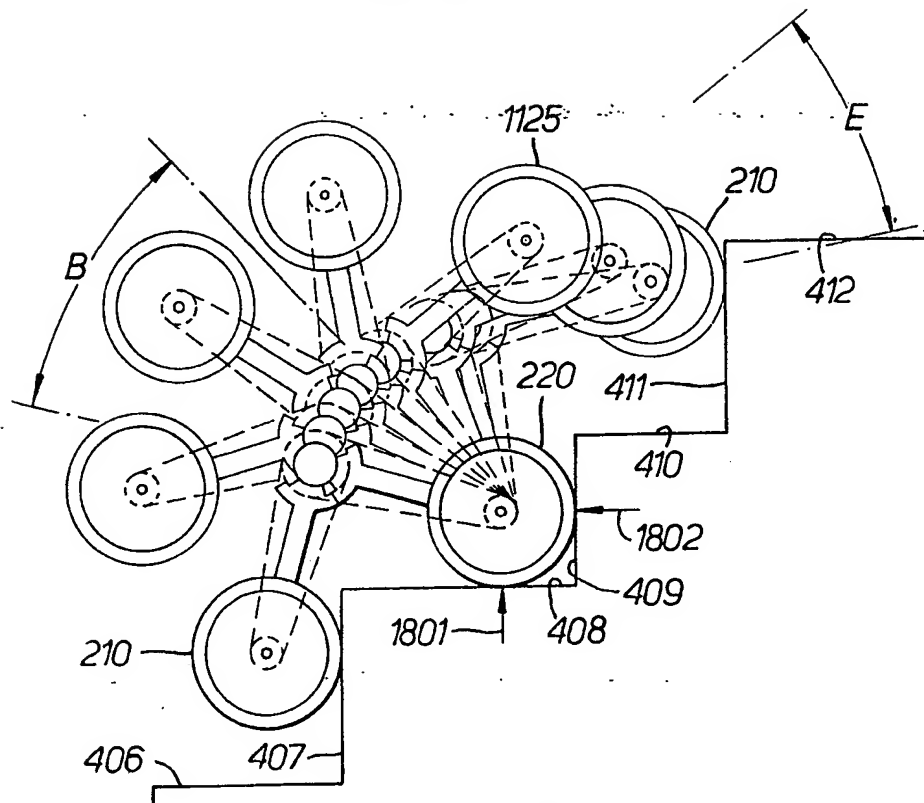


FIG. 11.

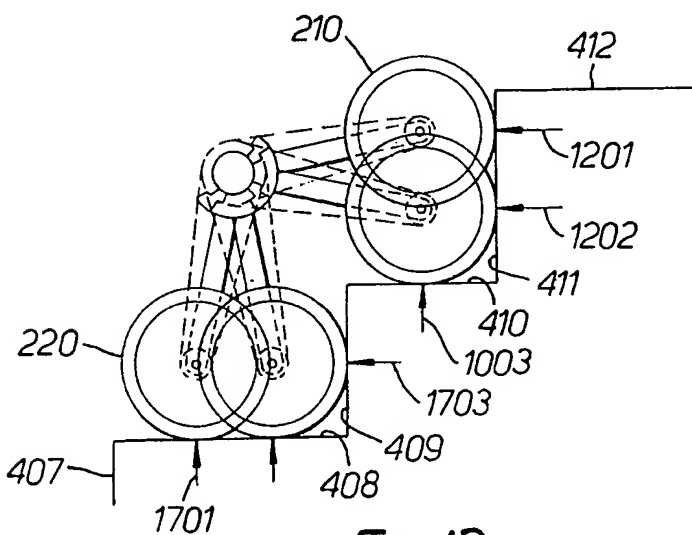


FIG. 12.

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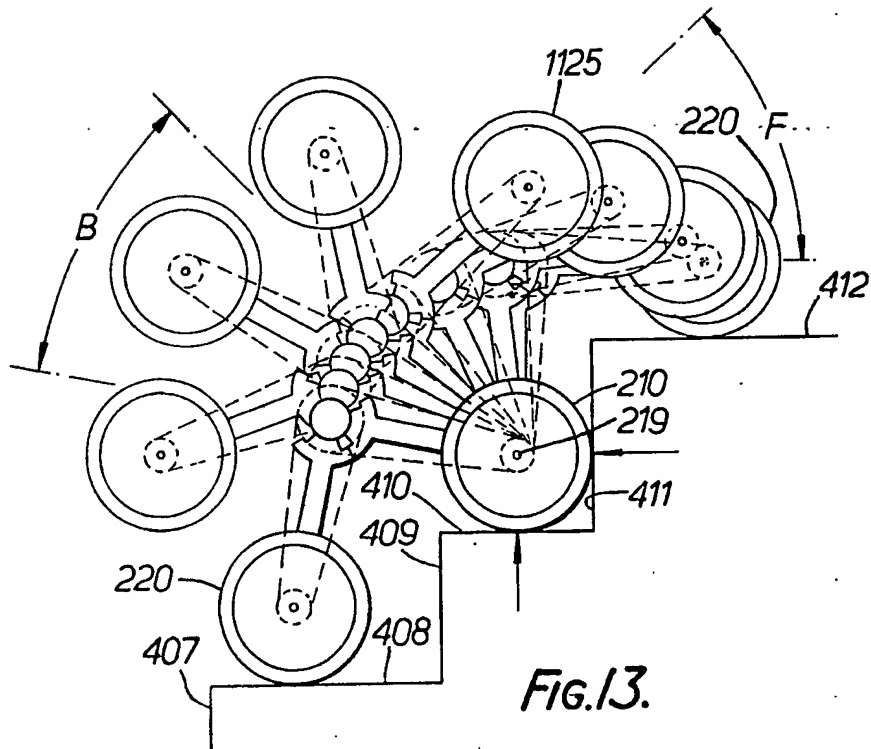


FIG. 13.

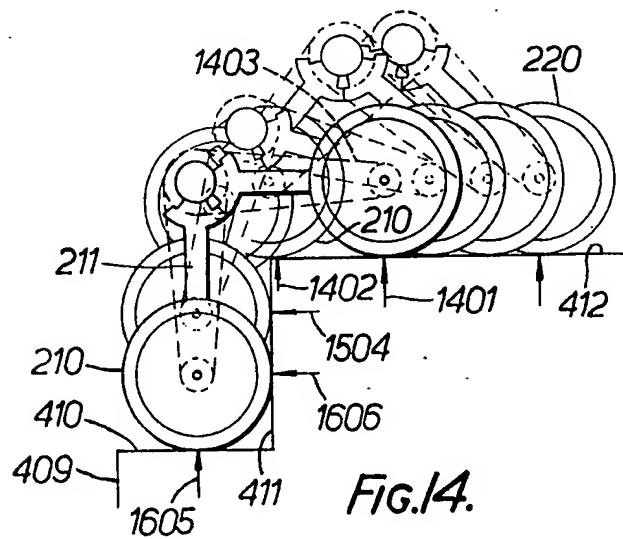


FIG. 14.

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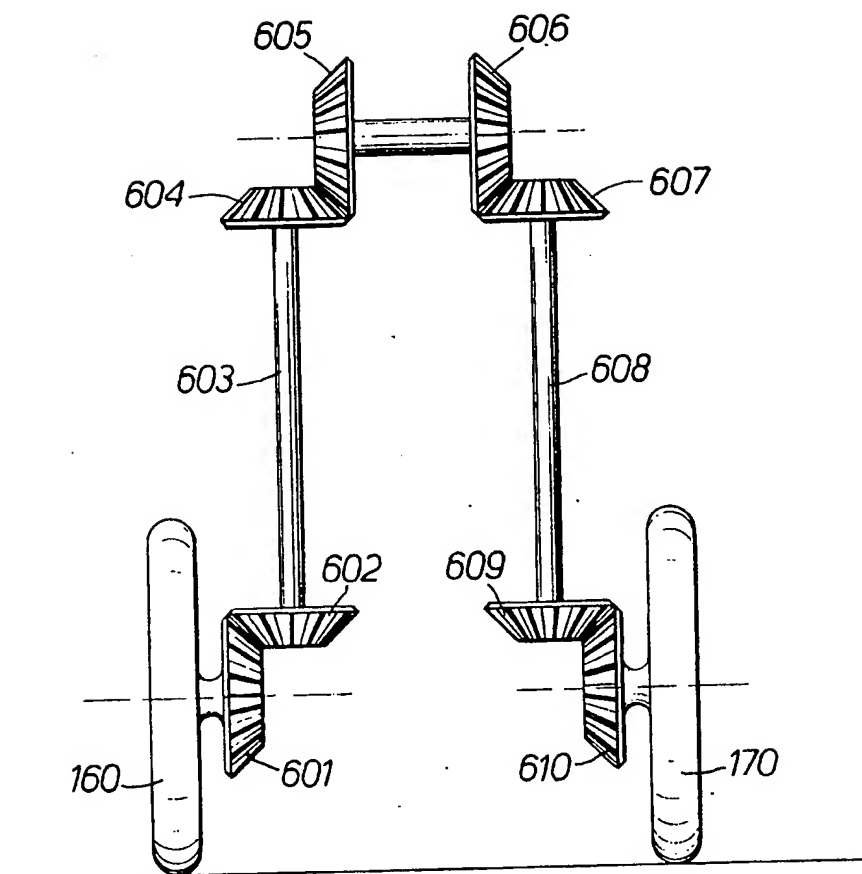


FIG. 15.

SPECIFICATION

Stair climbing devices

- 5 The present invention relates to stair climbing devices in particular to wheel chairs with reference to which it will be described.

- 10 There have been many proposals for stair climbing devices, some being for carrying people and incorporating a seat and others for carrying inanimate loads and then merely incorporating load carrying platforms.

- 15 The present invention is based on a novel concept of wheel assembly which provides a lifting force to smoothly lift a load up the stairs while also being effective for transporting a load along the flat. The wheel assembly has two independently rotatable wheels mounted on separate independently rotatable arms mounted on a common pivot axis. The basic principle of operation is to cause the leading wheel to drivingly engage the tread and riser of a step so as to hold the wheel from slipping off the step, rotate the arm about the wheel as a pivot by an angle less than 90° so as to raise the common pivot axis and then or simultaneously pivot the other arm around the common pivot axis in the same direction by more than 90° but not such as to cause the two wheels to interfere and preferably by an angle such that the angle between the arm after the movement is not less than 90° and particularly is 90°, and thereafter to continue pivoting the first arm until the wheel on the other arm contacts the next step.

- As is explained in more detail below this principle of operation enables the mechanism to climb a range of steps having significant variation in tread depth and riser height while at the same time ensuring safe and stable engagement of the steps.

- 40 According to the broadest aspect of the present invention a stair climbing device comprises load carrying means and one or more stair climbing wheel assemblies located in driving relationship to the load carrying means, each wheel assembly having two arms mounted for rotation about a common axis, each arm carrying a drivable wheel at or adjacent its end remote from the common axis, each arm being drivable around the common axis, and drive means whereby each wheel and each arm can be driven independently.

- 55 It will be appreciated that whilst mounting of the arms on a common axis is the most symmetrical arrangement and has benefits in avoiding any interference of the arms one with the other, other arrangements using parallel adjacent axes with the arms mounted on opposite faces of a member affording the axes could be used. For simplicity of description however the invention whilst not being limited to the axes in fact being common will be

described with reference to an arrangement in which they are.

- 70 When the arms are mounted so that interference between the wheels is possible it is desirable also to provide limiter means to ensure that the angle between the arms cannot be reduced to a value at which the wheels interfere with each other, the minimum angle preferably being 90°.

- 75 Reference has been made to the device having one wheel assembly. Hand trolleys are known having single auxiliary wheel assemblies to facilitate hand pushing up stairs. These do not have the climbing structure defined herein nor do they provide any lifting force, they merely smooth out the passage up the steps. Single wheel assemblies in accordance with the present invention may be built into such hand trolleys or may be provided for detachable securement to such trolleys.

- 80 Pairs of wheel assemblies may also be provided on conventional wheel chairs to assist manipulation of the wheel chair upstairs by a helper of the actual user of the chair. The wheel assemblies may be attached outboard of the rear wheels or inboard thereof or instead of the rear wheels. Such pairs of wheel assemblies also may be provided as detachable units for securement to existing wheel chairs or to replace the existing rear wheels of the wheel chair.

- 85 The device preferably comprises a pair of such stair climbing wheel assemblies located on either side of the load carrying means and most preferably two such pairs, one located adjacent the front of the device and one adjacent the rear.

- 100 Each arm and associated wheel is preferably provided with associated transducer means to sense upwards reaction and fore and aft reaction on the wheel. This enables the device to sense when it is on the flat or on a tread or when it has engaged the riser of a step and provides signals to initiate or control the step climbing sequence of movements which the device uses to climb stairs or descend stairs.

- 110 This transducer provision also enables the device to adjust its movements to accommodate flights of stairs of different tread depth or riser height or both from a previously climbed flight and provides a capability that earlier proposals do not seem to have possessed. In addition due to the fact that the device senses tread engagement and riser engagement for each step it can also handle flights of stairs in which the steps are not of even tread depth or riser height or both. Again this is a facility which earlier proposals do not seem to have possessed.

- 115 The invention thus also extends to a method of climbing stairs which comprises providing a stair climbing device in accordance with the invention, and then carrying out the following sequence of steps:
- 120 510) engaging with and driving into the

riser of the first step either the front wheel or wheels of the front wheel assembly or assemblies or the rear wheel or wheels of the rear wheel assembly or assemblies when front and

5 rear assemblies are present, (this assembly, which is the one which contacts the riser of the first step, being referred to as the leading assembly and the other assembly, if present, being referred to in the description of the
10 operation of the device as the trailing assembly, and this first engaged wheel being referred to as the first wheel and the other wheel as the second wheel; it should be borne in mind that after the second wheel has
15 completed a cycle of operation it becomes the first wheel),

515) locking the first wheel relative to the common axis or the member affording the common axis and then rotating the first arm
20 up through an angle of less than 90° e.g. less than 45° e.g. 30 to 40° relative to the first wheel axle,

520) driving the second arm up and around above the first arm about the common axis of
25 the wheel assembly and beyond it through an angle in excess of 90° e.g. at least 120 or 150° and preferably 170 to 190° e.g. 180°, steps 515) and 520) being carried out separately in any order or together,

30 525) driving the first arm towards the vertical or beyond (depending on the step dimensions) until the second wheel makes contact with the tread of the first step or the riser of the second step or both, and holding the first
35 arm there, e.g. by continuing the drive or by locking the drive or by actuating locking means,

530) sensing whether the contact is with the tread (upwards reaction here acting across
40 the arm) or the riser (fore and aft reaction here acting along the arm) or both,

535) if the contact is with the tread only, driving the wheel forwards towards the riser until contact with the riser is sensed,

45 540) if the contact is with the riser only driving the second arm further round and the first wheel backwards away from the riser until it is sensed that the second wheel is making contact with both the first tread and
50 the second riser,

545) driving the second wheel forwards towards the riser,

steps 550) to 580), the first arm and wheel now undergo the same sequence of operations as undergone by the second wheel and
55 arm and the second arm and wheel the operations undergone by the first in steps 515) to 545), and the cycle of steps 515) to 580) is continued until the absence of a riser is

60 sensed in step 535), under which condition the wheel sensing the absence of a riser reaction continues to be driven forward as if towards the riser and no rotational movement of the arm which is then the rear arm of the
65 assembly is initiated, instead the wheel of that

arm rises up the riser, the angle between the arms remaining the same, until this wheel also reaches the flat surface of the tread and landing of the top step, at which stage the climbing operation is complete.

The method of descending stairs comprises the following sequence of steps:

600) the wheel assembly is driven towards the edge of the top step,

75 605) the upwards reaction (here acting with components along the arm and transverse to the arm) on the wheel first reaching the edge of the top step (the first wheel) reducing as the axle of the wheel passes over the edge of the step and sensing when there is no upwards reaction but only fore and aft reaction from the riser of the top step,

610) driving the first wheel backwards (upstairs) towards and into the riser while continuing to drive the second wheel forwards (downstairs) as if away from the riser along the landing and tread of the top step,

615) sensing when there is both tread and riser reaction on the first wheel,

90 620) while continuing backwards driving of the first wheel towards the riser rotating the first arm from the vertical forwards downstairs and down towards the horizontal, through an angle of less than 90° e.g. less than 45° e.g.
95 30° to 40° relative to the first wheel axle,

625) rotating the second arm forwards downstairs and down about the common axis of the wheel assembly through an angle in excess of 90° e.g. at least 120° or 150° and preferably
100 170 to 190° e.g. 180°, steps 620) and 625) being carried out separately in any order or together,

630) driving the first arm towards the horizontal or beyond (depending on the step dimensions) until the second wheel makes contact with the tread of the third step from the top or the riser of the second step from the top or both,

635) sensing whether the contact of the second wheel is with the tread (upwards reaction) or the riser (fore and aft reaction) or both,

640) if the contact is with the tread only, driving the second wheel backwards towards and into the riser and the drive on the first wheel (which is now the rear wheel) being reduced to allow it to rise up the riser,

645) if the contact is with the riser only driving the second wheel forwards until it contacts the tread,

650) driving the second wheel backwards towards and into the tread and riser, steps 655 to 685), the first arm and wheel now undergo the same sequence of operations as undergone by the second arm and wheel and second arm and wheel the sequence of operations of the first arm and wheel in steps 620) to 650),

690) the cycle of steps 620) to 685) is repeated until the wheel which has just been

moved from the trailing to the leading position senses upward reaction but when driving backwards reaches a position where the relative angle between the arms is 90° and there is absence of riser reaction and that the arms are sensed to be equally disposed about a vertical line through the common axis of the arms, and

695) driving both wheels forward away from the riser together.

The load carrying means may be a common axle affording the common axes or a member joining the two common axes which may be afforded by stub axles which then are disposed in line. Alternatively the load carrying means may be a beam or beams or members adapted to be secured to a load carrying frame or platform e.g. symmetrically on either side of it, or when a single wheel assembly is provided at or adjacent the fore and aft centre line of the load carrying frame or platform e.g. at one end thereof.

In a preferred form of the invention the load carrying means are levers pivoted to a load carrying frame so that the orientation of the load carrying frame, whilst the device climbs the stairs, may be kept largely the same as it is when the device is on the flat.

More specifically a pair of load carrying means are provided on either side of the load carrying frame or platform and each may comprise a pair of levers pivoted to each other, one of the levers, the first lever, being pivoted at or adjacent its free end to the load carrying frame or platform at or adjacent its front end and the other lever, the second lever, being pivotally connected by a controllably extensible and retractable linkage which is pivotally secured to the load carrying frame or platform at a location remote from the point of location of the first lever, the wheel assembly or wheel assemblies being mounted on the second lever.

Thus according to a preferred specific form of the invention a vehicle capable of ascending and descending a straight flight of steps, comprises a load carrying frame e.g. in the form of an arm chair as in a conventional wheel chair, first and second levers pivoted to each other constituting the load carrying means, disposed on either side of the frame, the first lever being pivotally mounted on the frame, and extension means connecting the second lever to the frame, the extension means being such that the orientation of the second lever to the frame may be controllably adjusted, each second lever carrying first and second wheel assemblies each comprising at least two wheels, each mounted on an arm, each arm being independently mounted on the second lever, the arms in a wheel assembly being mounted on a common axis, and preferably on concentric axes and being independently drivable, each wheel also being independently drivable and drive means for

each wheel assembly whereby each wheel and each arm in an assembly can be independently and controllably driven, and preferably limiter means for the arms to ensure that the angle between the arms cannot be reduced to a value at which the wheels interfere with each other.

The first and second levers are preferably pivoted to each other at the front end of the second lever. Drive means may be provided so that the first levers can be drivingly rotated and held in any desired position relative to the second lever.

According to another aspect of the present invention a vehicle, for example a wheel chair, comprising a load carrying frame, for example a seat, arms and back rest located in a frame, has a pair of bell crank levers constituting the load carrying means, either side of the frame, each bell crank lever comprising first and second levers pivoted to each other, the first lever being pivotally mounted on the frame, and extension means connecting the second lever to the frame, the extension means being such that the orientation of the second lever to the frame may be controllably adjusted, each second lever carrying first and second wheel assemblies, drive means also being provided whereby each first lever can be drivingly rotated relative to the second lever to which it is pivoted, the arrangement being such that by extension of the extension means and operation of the drive means the load carrying frame can be elevated relative to the second levers.

This form of the invention provides a benefit independent of the stair climbing ability of the first aspect of the invention, namely that without leaving the chair the user can raise his eye level nearer to a normal standing height and is thus more easily able to converse with a standing person.

Returning now to the first aspect of the invention, the stair climbing embodiment, the front wheel assemblies are preferably mounted coaxially with the pivot between the first and second levers. The rear wheel assemblies are preferably mounted at or adjacent the rear of the second lever. Separate drive means are preferably provided for each wheel assembly and these may conveniently be mounted on the second lever desirably on flanges extending down from it so as to help lower the centre of gravity of the device and preferably inboard of the second levers so as to help keep the device as narrow as possible. The second lever, when the device is in the form of a wheel chair, preferably extends from in front of the seat to behind the rear of the seat e.g. so as to end below or just behind the back rest of the seat.

The location of each front drive motor is preferably in the front half of the second lever desirably nearer its mid-point than its front end. The location of each rear drive motor is

preferably just behind the rear mounting axle or common axis of each rear wheel assembly.

The motors are desirably controlled to be operable independently or in unison either
5 with a motor on its side of the device or with its companion front or rear motor or all together and at the same or different speeds.

The arms in each wheel assembly may be mounted coaxially by one arm having a hollow axle and the axle for the other arm passing through it. Each axle will then carry a drive member for its associated wheel as well as its own drive member. Each motor preferably drives its arms and wheels through torque
10 limiting means e.g. torque clutches which may be mechanical, electrical or hydraulic. The clutches may be individually provided for each wheel and each arm, or clutch means common to selected combinations of arms and wheels may be provided. The clutches
15 may be operable at preset or controllable torque values.

Locking means may be provided for the arms so that, on the flat, the wheel assemblies can be canted so that only one wheel of each assembly contacts the ground, and the arm is locked stably in that position. Only this wheel need then be driven. This, in reducing frictional contact with the ground, can be
20 expected to aid manoeuvrability of the device on the flat.

The sequence of operations of the preferred specific form of the invention described above having fore and aft wheel assemblies follows the same steps as described above for a single wheel assembly. The movements of the arms, that initially move through less than 90°, have to be carried out in unison but the movements of the arms that move through more than
30 90°, are preferably carried out separately so that at all times three wheels on each side of the device are being driven into the tread and riser of the step on which they rest.

This mode of operation is especially important when an extra high riser is being negotiated when two wheels will in fact be being driven only into the riser; such a circumstance makes it even more important for the arms which move through more than 90° to be actuated separately.
40

The extension means preferably extend from a location to the rear of the centre of gravity of the frame or platform of the device to a location on the second lever at or adjacent its mid-point e.g. between its mid-point and the middle of the front half of the second lever and preferably behind the front drive motor. The locations conveniently provide pivotal connections so that the extension means can freely pivot at least in a plane parallel to that of the second lever.
50

The extension means may be a screw or ratchet mechanism e.g. driven by an offtake from the front drive motor or a separate motor
55 or may be a hydraulic cylinder and piston

supplied with hydraulic fluid from a pump which could again be driven by the front drive motor or another motor. Whatever form the extension means takes it is desirably controllable and preferably under the control of level sensing means so as to operate to keep the orientation of the frame or platform the same while the device climbs or descends stairs as when it is on the flat.
70

Consideration of the centre of gravity of a wheel chair carrying a person indicates that the most stable configuration for climbing stairs is for the wheel chair to go up backwards (from the point of view of the person sitting in the chair) and come down forwards and this is the preferred mode of operation for the device according to the present invention when in the form of a wheel chair.
75

The present invention can be put into practice in various ways and one specific embodiment will be described to illustrate the invention with reference to the accompanying drawings in which:
80

Figure 1 is a front elevation of the vehicle in the form of a wheelchair for a person who has lost the use of their legs:
85

Figure 2 is a side elevation of the wheelchair showing it in the orientation it adopts on a flat horizontal surface but also showing it with the frame and seat in a raised position;
90

Figure 3 is partial view similar to Figure 2 on an enlarged scale showing the movable chassis and wheel assembly arrangement of the invention in more detail;
95

Figures 4, 5 and 6 are side elevational views showing stages in a stair climbing or a stair descending cycle for the device according to the invention;
100

Figure 4 shows the stage where the first wheel of the leading wheel assembly has started to descend the top step;
105

Figure 5 shows a further stage where the rear wheels of the leading and trailing wheel assemblies are each resting on a step but the steps are the top and third steps of the sequence of steps and the front wheel of the trailing wheel assembly is just about to make contact with the second step tread, and the front wheel of the leading wheel assembly is just about to make contact with the fourth step tread;
110

Figure 6 shows a further position in which the front wheel of each wheel assembly is rotating out down towards the flat surface onto which the machine will eventually rest;
115

Figures 7 to 14 illustrate by reference only to a single wheel assembly how the wheel assembly climbs and descends a flight of stairs;
120

Figure 15 is a diagrammatic front elevation showing an alternative arrangement of wheel mounting.
125

The general structure and assembly of the wheel chair will now be described with refer-
130

ence to Figures 1, 2 and 3; thereafter the mode of operation will be described with reference to Figures 4 to 14.

Referring to Figures 1, 2 and 3 the chair
 5 has a load carrying frame 10 e.g. made of tubular metal which supports a back rest, seat, and arm rests and depending from beneath the seat a battery carrying framework 30. A controllable ball and screw cylinder
 10 400 is pivotally mounted by a pivotal connection at each side of the side supports beneath the seat and to the rear of the centre of gravity. The cylinders are driven by power take offs from motors which are controllable
 15 so as to cause the pistons to extend or retract in a controlled manner.

A floating chassis is located outside the lower portion of the frame and extends longitudinally thereof on each side of the frame:
 20 This chassis consists of a pair of first and second levers pivoted to each other and extending longitudinally of the frame. The second lever 100 is pivoted to the first lever 110 which is attached to the frame by a pivotal linkage at the front of the frame. Each lever 110 is provided with drive means (not shown for clarity in the drawings) whereby it can be rotated in either direction around the pivot 121 and held in any desired angular relationship to the lever 100 to which it is pivoted.
 30 Each second lever 100 is also attached to the frame by the above-mentioned cylinders 400 at the rear. Each cylinder 400 is pivoted adjacent the mid-point of its second lever 100
 35 at its lower end and at its upper end to the pivotal connection on the underside of the side frame beneath the seat. Each second lever carries at its front and rear end a wheel assembly 150 and 200 each having arms
 40 pivoted to the ends of the second levers, the arms being drivably rotatable around their pivots 121 and 141 respectively.

Each second lever also carries at a location between its front end and the pivot point for the lower end of the cylinder a front wheel assembly drive motor 300 and below and just behind the rear of each second lever there is a rear wheel assembly drive motor 350 similarly mounted. These motors are mounted so as to
 50 extend inboard of the second levers so as not to interfere with the wheels of the wheel assemblies. The front wheel assembly motor 300 is also positioned at a distance below the floating chassis such that it does not interfere with the power pack carrying framework 30.
 55 Each front wheel assembly motor 300 has a drive output shaft connected via a drive belt or chain to a drive wheel at the front end of its second lever which itself is connected to

60 drive wheels for each of the wheel structures 160, 170, 180, 190 (not shown) on the front wheel assembly 150 and these drive wheels are connected by chains or belts to drive shafts at the wheel structures. A similar drive
 65 arrangement is provided for the wheel struc-

tures 210, 220 and 230 (not shown), 240 (not shown) of the rear wheel assembly 200.

In more detail the frame 10 has back and seat supporting side members 11 and 12
 70 each affording rearwards extending handles 13. Armrest and front side members 14 and 15 are welded to the side members 11 and 12 from between the seat and the backrest at 16 and extend therefrom up to an arm rest position and down past the ends of the members 11 and 12 to which they are again
 75 welded at 17.

Front and rear cross members 18 (not shown) are welded to the side members 11 and 12 between the points 16, 16 and 17, 17.
 80

The side members 14 and 15 extend down below foot level at the front and then curve up again at 19 to afford forwardly extending upwardly canted ends 21 which carry inwardly facing footrests 22.
 85

The side members 11 and 12 at the rear of the seat 26 between the back of the frame work 30 and the position 16 are provided with downwardly extending ears 23 and 24
 90 (not shown) affording pivotal bearings 25 and 26 (not shown).

The side members 14 and 15 have outwardly extending pins or shafts 27 and 28 (not shown) adapted to provide a pivotal connection in the region 19, the lowest point of their front ends.
 95

The purpose of the pins 27 and 28 (not shown) and bearings 25 and 26 will be described below.

100 The battery or power pack carrying framework 30 affords further cross bracing of the frame 10 and as can be seen in Figure 1 consists of a pair of rear members 31 which extend down from the side frames 11 and 12
 105 at each side from a position just in front of the centre of gravity 33 of the device then inwardly at 34, down at 35 and across to provide a cross member 36. Side members 37 extend forward at the bottom of the framework 30 at each side and then up at 38 and back out at 39 to the side members 14 and 15 to which they are welded at 40.

The battery and control mechanisms can be mounted in this space.

115 The structure of the second levers 100 of the bell crank levers affording the floating chassis will now be described in more detail.

Each second lever is of generally flattened elongated dumbbell or connecting rod or plate shape, having round enlarged ends 120, 140 affording common pivots 121 and 141 and a strip like rod portion 130.
 120

Each second lever has a flange 125 extending down from the bottom edge of the second lever in its front half.
 125

This flange affords a mounting 126 (not shown) for a front wheel assembly drive motor 300 and also a pivot pin or bearing for the other end of the ball and screw cylinder 400.

130 Each second lever also has a rearward ex-

tension 142 beyond the rear enlarged end 140 on which a rear wheel assembly drive motor 350 is mounted.

The mounting of the frame 10 on the floating chassis will now be described in more detail.

As mentioned above the floating chassis comprises a second lever 100 pivoted to a first lever 110 at the front. Each first lever 110 is pivoted at one end via a slot 111 to the pin 27 or 28 and at the other end to the second lever, so that the first lever can pivot in a fore and aft direction relative to the second lever and the wheelchair.

This allows the second levers to move from a position parallel to the seat bottom where the end 120 is directly above the region 19 as shown in Figures 2 and 3 to a position in which it is below and in front of the region 19 and the second lever 100 is at an angle of about 40° to the seat bottom as shown in Figures 5 and 6. The first lever 110 in moving from the position shown in Figure 3 to that shown in Figures 5 and 6 has moved through about 150°, i.e. relative to the straight portion 17 of the side frame from about 15° to about 165°. This movement is brought about by extension of the piston 401 of the cylinder from its retracted position (shown in Figure 3) via a partly extended position (shown in Figure 4) to a more fully extended position (shown in Figures 5 and 6).

The mounting of the wheel assemblies on the second levers will now be described in more detail.

The front wheel assemblies 150 have front wheel structures 160, and 180 (see Figure 1) and rear wheel structures 170 and 190 (not visible). Similarly the rear wheel assemblies 200 have front wheel structures 210 and 220 (not visible) and 230 and 240 (not visible).

Each wheel structure, in each wheel assembly is independently pivotally connected to its second lever. Each wheel structure is in fact a pair of wheels and for example, for the wheel structure 160, is mounted on a wheel carrying arm 161 which has one end located between the pair of wheels and the other end pivoted to the end 120 of the second lever 100.

Each wheel structure, has a drive wheel e.g. 162 for wheel structure 160 which is keyed to or formed with, e.g. integrally with, the wheel 160 which is driven by a belt drive 163 from a drive wheel 164 mounted on the end 120. Wheel structure 170 is similarly driven via a drive wheel 172, belt 173 and drive wheel 174. Drive wheels 162, 164, 172 and 174 are all the same diameter.

In an alternative arrangement shown in Figure 15 each wheel structure has a bevel gear drive wheel e.g. 601 for the wheel structure 160 which is keyed to or formed with, e.g. integrally with, the wheel 160, drive wheel 601 being driven by a mating bevel gear

wheel 602 which is driven by a shaft 603. The shaft 603 is driven by a bevel gear 604 which is driven by a bevel gear 605. The wheel structure 170 is similarly driven via a drive wheel 610, a bevel 609, a shaft 608, a bevel 607 and a bevel gear 606. Bevel gears 602, 604, 607 and 609 have the same pitch circle diameter. Bevel gears 601, 610, 606 and 605 have the same pitch circle diameter.

The drive wheel 164 is keyed to or formed from the drive wheel 174, (in the alternative arrangement of Figure 15, the drive wheel 605 is keyed to or formed with, e.g. integrally with, the drive wheel 606). These wheels 164 and 174 (or 605 and 606) are mounted on a shaft to which a drive wheel 304 is keyed to or formed with, e.g. integrally with. The wheel 304 is driven by a belt 303 from the drive wheel 302 of the front drive motor 300.

The drive wheels 164 and 174 incorporate controllable torque clutches so that they can be driven in either direction. When not being driven they are locked relative to the lever 100 this causes the wheel structures 160 and 170 to be fixed in relationship to the surface on which the wheel structures 160 and 170 are resting, this relationship being unaffected by the movement of the arms 161 and 171.

The drive arrangement for the rear wheel assemblies 200 is the same.

As mentioned above the wheel structures of each wheel assembly are mounted on arms which are independently pivotally mounted on the second levers and are independently driveable by the drive motors.

For ease of reference and clarity in the drawings these will be described for the rear wheel assembly 200 (see Figure 3) (the arms 161 and 171 associated with the front wheel assembly have been omitted in Figure 3). Thus referring to Figure 3 the arm 211 is freely mounted on the shaft to which the drive wheel 304 is keyed, this arm 211 has a drive wheel which incorporates a controllable torque clutch so that the arm can be driven in either direction by the shaft. The arm 221 is also freely mounted on the shaft to which the drive wheel 304 is keyed, this arm 221 is provided with a drive wheel and clutches in the same way as arm 211.

The arms can be locked relative to the chassis by any suitable means. Thus the drive by which the arms can be rotated relative to the common axis can be a worm and screw drive, which gives good reduction, smooth action and safety, being irreversible.

The arms 211 and 221 also have stop structures. These limit the closest approach of the arms 211 and 221 to 90° and consist of radial faces 216 and 226 affording lower stop structures and 217 and 227 affording upper stop structures.

The arms also carry transducers 218 and 228 arranged to sense reactions on the wheels. These are upwards floor or tread

reactions and fore and aft riser reactions. The floor or tread reactions when the vehicle is on the flat will have components along and across the arm but when the device is climbing or descending will be either substantially along the arm when it is vertical or across the arm when it is horizontal.

The fore and aft reactions are those produced by the risers; when the device first encounters a riser on climbing stairs the first riser reaction will have components both along and across the arm but again once climbing has commenced the riser reaction will be along the arm when the arm is horizontal or across it when the arm is vertical.

These transducers supply the signals which control the climbing and descending routines.

Figures 7 to 14 illustrate by reference only to a single wheel assembly how the wheel assembly climbs and descends a flight of stairs. Figures 7, 8 and 14 illustrate the sequences involved for a flight with steps of equal tread depth and riser height throughout, Figure 7 being the bottom step sequence and Figure 14 the top step sequence and Figure 8 the sequence of intermediate steps.

Figures 9 to 11 illustrate how the device accommodates steps which have a deeper tread than riser height and Figures 11 to 13 illustrate how the device accommodates steps which have a shallower tread than riser height. Figures 7 to 14 illustrate the movements of the descending sequence except that the trajectories of the arching over wheel differ between climbing and descending as will be described below.

The Figures are shown in the drawings in pairs, 7 and 8 aligned on the first riser 401, 9 and 10 aligned on the fourth riser 407, 11 and 12 aligned on the fifth riser 409, and 13 and 14 aligned on the sixth riser 411.

As mentioned above the wheel chair climbs stairs backwards.

Thus in Figure 7 it is the rearmost wheel structure 220 which rolling along the ground 400 engages the riser 401 of the first step. The rear wheel assembly as shown in Figure 7 is initially in the condition shown in Figure 3 with the lower stop member 216 on the arm 211 engaging the lower stop member 226 on the arm 221 so that the angle between the arms 211 and 221 is 90°.

The routine followed in Figure 7 involves the following steps:

710) the wheel structure 220 (the first wheel) engages the riser 401,

715) the transducer 228 on the arm 221 senses and confirms the upwards tread reaction 420 and the fore and aft riser reaction 421 on the first wheel,

720) the arm 221 is driven by the motor 350 in a forward upstairs direction through an angle A, preferably of 36°, around the axle 229 of the wheel structure 220,

730) the arm 211 is driven by the motor

350 in a forward upstairs direction around the common pivot 141 through an angle relative to the pivot of 180° till the wheel structure 210 (the second wheel) occupies the position 425 shown in Figure 7 and the upper stops 217 and 227 of the arms 211 and 221 are in engagement, (steps 720 and 730 are preferably carried out in unison), 740) the first arm 221 now is driven by the motor 350 further forward in an upstairs direction around the axle 229 of the wheel structure 220 through an angle C until the second wheel contacts the tread 402 or riser 403 or both.

The routine followed in Figure 8 involves the following steps:

815) the transducer 218 on the arm 211 senses whether there is upwards tread reaction 426 or fore and aft riser reaction 427 on the wheel structure 210 or as in this case both and confirms this,

820) the arm 211 is driven by the motor 350 in a forward upstairs direction through an angle A, preferably of 36°, around the axle 219 of the wheel structure 210,

830) the arm 221 is driven by the motor 350 in a forward upstairs direction around the common pivot 141 through an angle B, relative to the pivot, of 180° till the wheel structure 220 (the second wheel) occupies the position 428 shown in Figure 8 and the lower stops 216 and 226 of the arms 211 and 221 are in engagement (steps 920 and 930 are preferably carried out in unison),

940) the second arm 211 now is driven by the motor 350 further forward in an upstairs direction around the axle 219 of the wheel structure 210 through an angle D (the value of which depends on the step) until the first wheel 220 contacts the tread 404 or riser 405 or both.

The alternating routine described for Figures 7 and 8 namely steps 720 to 740 and 815 to 840 is now followed repeatedly so long as the steps remain of equal tread depth and riser height until the top step is reached as shown in Figure 14.

Assuming an even number of steps (there are in fact 6) the routine (1400) in Figure 14 involves the following steps:

1415) the transducer 228 on the arm 221 senses and confirms the upwards tread reaction 1401 on the first wheel 220,

1420) the motor 350 is used to drive the wheel 220 along the tread and landing 412 and the wheel 210 is allowed to rise up the riser 411,

1430) the transducer 218 on the arm 211 senses upwards tread reaction 1402 on the wheel 210 once the position 1403 is reached,

1420) both the wheels 210 and 220 are now driven forward.

The way in which the device deals with steps of unequal tread depth and riser height will now be described.

The routine followed in Figure 9 involves the same steps as followed in Figure 8 except that in step 915, it is the tread 406 and the riser 407 and at the end of the sequence the wheel 220 rests on the tread 408 but is not in contact with the riser 409 the depth of the tread 408 being less than the height of the riser 407.

The routine followed next is that shown in Figure 10 which involves the following steps: 1015) the transducer 228 on the arm 221 senses that there is an upwards tread reaction 481 only on the wheel 220 from the tread 408,

1020) the wheel 220 is driven by the motor 350 into the riser 409 and the wheel 210 on the arm 211 is allowed to rise up the riser 407, raising the common pivot axis 141.

The routine followed next is that shown in Figure 11 and it shows both the end of the procedure for handling a deep tread and also the beginning of the procedure for handling a shallow tread; it involves the following steps:

1115) the transducer 228 on the arm 221 senses and confirms the tread reaction at 482 and the riser reaction 483,

1120) the arm 221 is driven by the motor 350 in a forward upstairs direction through an angle A, preferably of 36° , around the axle 229 of the wheel structure 220,

1130) the arm 211 is driven by the motor 350 in a forward upstairs direction around the common pivot 141 through an angle relative to the pivot of 180° till the wheel structure 210 (the second wheel) occupies the position 25 shown in Figure 11 and the upper stops 217 and 227 of the arms 211 and 221 are in engagement, (steps 1120 and 1130 are preferably carried out in unison),

1140) the first arm 221 now is driven by the motor 350 further forward in an upstairs direction around the axle 229 of the wheel structure 220 through angle E until the second wheel contacts the riser 411.

The routine followed next is that shown in Figure 12 and it involves the following steps:

1215) the transducer 218 on the arm 211 senses and confirms that there is a riser reaction at 1201 only,

1220) the wheel 210 on the arm 211 is allowed to drop down the riser 411 and the wheel 220 is driven backwards along the tread 408 by the motor 350,

1225) the transducer 218 on the arm 211 senses and confirms the riser reaction at 1202 and the tread reaction at 1003.

The routine followed next is that shown in Figure 13 and consists of steps 1320, 1330 and 1340 analogous to steps 1120 to 1140 for Figure 11, except that the angle F in step 1340 is greater than the angle E in step 1140 and the wheel 220 comes to rest on the tread 412 ready for the procedure of Figure 14 which has already been described.

The descending operation is carried out

with the front wheel assembly leading. The procedure is then analogous to the climbing procedure and it is thought unnecessary to supply additional drawings.

Essentially the front wheel assembly 150 is now involved instead of the rear wheel assembly 200 and the first or leading wheel structure is 160 and the second or trailing wheel structure is 170.

The movements of the arms 161 and 171 are downstairs (anticlockwise in the drawings) however to ensure that the wheels remain firmly urged into the confluence of tread and riser the rotation of the wheels 160 and 170 is usually clockwise. The initial movement of the arms, as in the climbing mode, is still through angle A and it will be appreciated that this now occurs in the initial movement of the arm from the vertical towards the horizontal rather than vice versa as in the climbing mode. This causes a difference in trajectory of the wheel which is arching over on the arm which moves through the angle B. In addition the transducers sense reactions in the lower wheel rather than the upper wheel.

Apart from these differences the descending procedure closely mirrors the climbing procedure.

Thus the initial step is shown in Figure 14, if reference 160 replaces 210 and 161 replaces 211 and 170 replaces 220, the routine (1500) involves the following sequence of steps:

1505) the wheels 160 and 170 are driven by the motor 300 towards the edge of the step 412,

1510) the axle 169 of the wheel 160 passes over the edge and the transducer 168 on the arm 161 senses a drop in upwards reaction to zero and reverses the direction of drive of the wheel 160 and senses riser reaction pressure 1504, while the wheel 170 continues to be driven downstairs (anticlockwise).

The next step is shown in Figure 13 and the routine (1600) involves the following steps:

1615) the transducer 168 on the arm 161 senses and confirms upwards tread reaction 1605 and riser reaction 1606,

1620) the arm 161 is driven by the motor 300 in a downstairs (anticlockwise) direction through an angle A preferably of 36° , around the axle 169 of the wheel structure 160,

1630) the arm 171 is driven by the motor 300 in a downstairs direction around the common pivot 121 through an angle, B, relative to the pivot of 180° till the upper stops 167 and 177 of the arms 161 and 171 are in engagement (steps 1620 and 1630 are preferably carried out in unison),

1640) the first arm 161 now is driven by the motor 300 further downwards around the axle 169 of the wheel structure 160 through an angle F until the second wheel 170 con-

tinues to be driven downstairs (anticlockwise).

The next step is shown in Figure 13 and the routine (1600) involves the following steps:

tacts the tread 407.

The next step is shown in Figure 12 and the routine (1700) involves the following steps:

5 1715) the transducer 178 on the arm 171 senses and confirms an upwards tread reaction 1501 only on the wheel 170,

1720) the wheel 170 is driven clockwise into the confluence of the tread 408 and riser 409 by the motor 300 and the wheel 160 is allowed to rise up the riser 411.

The next step is shown in Figure 11 and the routine (1800) is analogous to that described for the climbing sequence for Figure 11 but modified as indicated above for the descending sequence.

The routines for Figures 10, 9 and 8 are similarly analogous to the climbing routines described for these Figures but modified as already indicated.

The routine when the chair reaches the floor or landing at the bottom of the flight (Figure 7) is as follows: The wheel 170 is driven clockwise into the confluence of the tread 400 and the riser 401 sensing reactions 420 and 421, the arm 161 is driven forwards and downwards until the wheel 160 contacts the tread 400. The wheel 160 is then driven clockwise until the stops 216 and 226 are in contact at which time the arms are at 90° to one another and symmetrically disposed about a vertical line through the common axis of the arms, the logic is completed by the absence of a horizontal reaction at the wheel 160.

By this logic the assembly is known to have reached a landing or floor at the bottom of a flight.

CLAIMS

40 1. A stair climbing device comprising load carrying means and one or more stair climbing wheel assemblies located in driving relationship to the load carrying means, each wheel assembly having a pair of arms
45 mounted for rotation about a common axis, each arm carrying a drivable wheel at or adjacent its end remote from the common axis, each arm being drivable around the common axis, and drive means whereby each
50 wheel and each arm can be driven independently.

2. A device as claimed in Claim 1 in which the minimum angle between the arms is 90°.

3. A device as claimed in Claim 1 or Claim 55 2 which comprises two pairs of stair climbing wheel assemblies located on either side of the load carrying means, one pair located adjacent the front of the device and one pair adjacent the rear.

60 4. A device as claimed in Claim 1, 2 or 3 in which each arm and associated wheel is provided with associated transducer means to sense upwards reaction and fore and aft reaction on the wheel, and the transducer means
65 are used to provide signals to initiate or

control the step climbing sequence of movements which the device uses to climb stairs or descend stairs.

5. A device as claimed in Claim 1, 2, 3 or 70 4 in which the load carrying means are levers pivoted to a load carrying frame so that the orientation of the load carrying frame, whilst the device climbs the stairs, may be kept largely the same as it is when the device is on the flat.

6. A device as claimed in any one of Claims 1 to 5 in which a pair of load carrying means are provided on either side of the load carrying frame or platform, each comprising a pair of levers pivoted to each other, one of the levers, the first lever, being pivoted at or adjacent its free end to the load carrying frame or platform at or adjacent its front end and the other lever, the second lever, being
80 pivotally connected by a controllably extensible and retractable linkage which is pivotally secured to the load carrying frame or platform at a location remote from the point of location of the first lever, the wheel assembly or wheel
85 assemblies being mounted on the second lever.

7. A vehicle capable of ascending and descending a straight flight of steps, comprising a load carrying frame, first and second levers pivoted to each other constituting the load carrying means, disposed on either side of the frame, the first lever being pivotally mounted on the frame, and extension means connecting the second lever to the frame, the extension means being such that the orientation of the second lever to the frame may be controllably adjusted, each second lever carrying first and second wheel assemblies each comprising at least two wheels, each mounted on an arm,
100 each arm being independently mounted on the second lever, the arms in a wheel assembly being mounted on a common axis and being independently drivable, each wheel also being independently drivable and drive means
105 for each wheel assembly whereby each wheel and each arm in an assembly can be independently and controllably driven.

8. A device as claimed in Claim 7 in which the first and second levers are pivoted to each other at the front end of the second lever, and the front wheel assemblies are mounted coaxially with the pivot between the first and second levers.

9. A device as claimed in any one of Claims 120 6 to 8 in which separate drive means are provided for each wheel assembly mounted on the second lever on flanges extending down from it and inboard of the second levers.

10. A device as claimed in Claim 1 substantially as specifically described herein with reference to the accompanying drawings.

11. A method of climbing stairs which comprises providing a stair climbing device as
130 claimed in any one of Claims 1 to 10, and

then carrying out the following sequence of steps:

- 510) engaging with and driving into the riser of the first step either the front wheel or wheels of the wheel assembly or assemblies or the rear wheel or wheels of the rear wheel assembly or assemblies when front and rear assemblies are present, (this assembly being referred to as the leading assembly and the other assembly, if present, being referred to as the trailing assembly, and this first engaged wheel being referred to as the first wheel and the other wheel as the second wheel),
- 515) while continuing upstairs driving of the first wheel rotating the first arm up through an angle of less than 90° relative to the first wheel axle,
- 520) driving the second arm up and around above the first arm about the common axis of the wheel assembly and beyond it through an angle in excess of 90° , steps 20) and 30) being carried out separately in any order or together,
- 525) driving the first arm towards the vertical or beyond (depending on the step dimensions) until the second wheel makes contact with the tread of the first step or the riser of the second step or both, and holding the first arm there, 530) sensing whether the contact is with the tread (upwards reaction here acting across the arm) or the riser (fore and aft reaction here acting along the arm) or both, 535) if the contact is with the tread only, driving the wheel forwards towards the riser until contact with the riser is sensed, 540) if the contact is with the riser only driving the second arm further round and the first wheel backwards away from the riser until it is sensed that the second wheel is making contact with both the first tread and the second riser, 545) driving the second wheel forwards towards the riser, steps 550) to 580), the first arm and wheel now undergo the same sequence of operations as undergone by the second wheel and arm and the second arm and wheel the operations undergone by the first in steps 515) to 545), and the cycle of steps 515) to 580) is continued until the absence of a riser is sensed in step 535), under which condition the wheel sensing the absence of a riser reaction continues to be driven forward as if towards the riser and no rotational movement of the arm which is then the rear arm of the assembly is initiated, instead the wheel of that arm rises up the riser, the angle between the arms remaining the same, until this wheel also reaches the flat surface of the tread and landing of the top step, at which stage the climbing operation is complete.

12. A method of descending stairs which comprises

- providing a stair climbing device as claimed in any one of Claims 1 to 10, and then

carrying out the following sequence of steps:
600) the wheel assembly is driven towards the edge of the top step,

- 605) the upwards reaction (here acting with components along the arm and transverse to the arm) on the wheel first reaching the edge of the top step (the first wheel) reducing as the axle of the wheel passes over the edge of the step and sensing when there is no upwards reaction but only fore and aft reaction from the riser of the top step,
- 610) driving the first wheel backwards (upstairs) towards and into the riser while continuing to drive the second wheel forwards (downstairs) as if away from the riser along the landing and tread of the top step,
- 615) sensing when there is both tread and riser reaction on the first wheel,
- 620) while continuing backwards driving of the first wheel towards the riser rotating the first arm from the vertical forwards downstairs and down towards the horizontal, through an angle of less than 90° relative to the first wheel axle,
- 625) rotating the second arm forwards downstairs and down about the common axis of the wheel assembly through an angle in excess of 90° , steps 620) and 625) being carried out separately in any order or together,
- 630) driving the first arm towards the horizontal or beyond (depending on the step dimensions) until the second wheel makes contact with the tread of the third step from the top or the riser of the second step from the top or both,
- 635) sensing whether the contact of the second wheel is with the tread (upwards reaction) or the riser (fore and aft reaction) or both,
- 640) if the contact is with the tread only, driving the second wheel backwards towards and into the riser and the drive on the first wheel (which is now the rear wheel) being reduced to allow it to rise up the riser,
- 645) if the contact is with the riser only driving the second wheel forwards until it contacts the tread,
- 650) driving the second wheel backwards towards and into the tread and riser, steps 655 to 685), the first arm and wheel now undergo the same sequence of operations as undergone by the second arm and wheel and second arm and wheel the sequence of operations of the first arm and wheel in steps 620) to 650),
- 690) the cycle of steps 620) to 685) is repeated until upwards reaction on the wheel which has just been moved from the trailing to the leading position is sensed before the arms on the wheel then engaging a tread and a riser is sensed to have moved through 90° , and
- 695) driving both wheels forward away from the riser together.

13. A method as claimed in Claim 11 or Claim 12 as applied to a device as claimed in any one of Claims 6 to 10 in which the movements of the arms, that move initially through less than 90°, are carried out in unison but the movements of the arms that move through more than 90°, are carried out separately so that at all times three wheels on each side of the device are being driven into the tread or riser or both of the step on which they rest.

14. A method as claimed in Claim 11, 12 or 13 substantially as specifically described herein with reference to the accompanying drawings.

15. A vehicle comprising a load carrying frame, first and second levers pivoted to each other constituting the load carrying means, disposed on either side of the frame, the first lever being pivotally mounted on the frame, and extension means connecting the second lever to the frame, the extension means being such that the orientation of the second lever to the frame may be controllably adjusted, each second lever carrying first and second wheel assemblies, drive means also being provided whereby each first lever can be drivingly rotated relative the second lever to which it is pivoted, the arrangement being such that by extension of the extension means and operation of the drive means the load carrying frame can be elevated relative to the second levers.

16. A device as claimed in Claim 15 in which the first and second levers are pivoted to each other at the front end of the second lever, and the front wheel assemblies are mounted coaxially with the pivot between the first and second levers.

17. A vehicle as claimed in Claim 15 or Claim 16 and as claimed in any one of Claims 1 to 9.